Efficacy of the "Mitchell Station," a New Bait-Station for the Control of the Caribbean Fruit Fly, *Anastrepha suspensa* (Loew) (Diptera: Tephritidae)

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Abstract. Insecticide bait sprays for the control of fruit flies are often applied to nonagricultural areas. As a result urban populations and environmentalists have expressed concerns for both human health and the conservation of nontarget organisms. One alternative to bait sprays is the deployment of portable bait units which attract pests to a limited number of sites and there expose them to the toxicant. The late Dr. Everett Mitchell designed such an "attract and kill" device and considered the possibility of its use in fruit fly suppression / eradication programs. The ability of this "Mitchell Station" (=MS), with or without the addition of an ammonium acetate and putrescine attractant, to kill Caribbean fruit flies (*Anastrepha suspensa* [Loew]) was compared in field cages to the standard McPhail and Multi Lure® traps. The MS station was not as efficient as either the McPhail or Multi-lure traps. However, it would be considerably less expensive to manufacture and deploy, and might find a niche within area-wide management programs. Subsequent deployment of the MS in the field significantly suppressed previously released populations of sterile *A. suspensa*.

Key words: Permethrin, Teflon®, area-wide management, attract and kill

Introduction

Tephritid fruit flies attack multiple species of fruits and vegetables and are often the cause of trade barriers that hinder the growth of agricultural economies (Liquido et al. 1990, Aluja 1996). For example, establishment of *Ceratitis capitata* (Wiedemann), the Mediterranean fruit fly, in the continental United States would result in annual losses of ~$1.1 billion in California alone due to embargos, job losses, increased pesticide use, and crop loss (Siebert & Pradhan 1991). In addition to infesting commercial plantings, pest fruit flies are typically present in wild and residential plants (e.g., Norrbom & Kim 1988), and chemical control in these environments has generated considerable controversy (e.g., Headrick & Goeden 1996). The typical means of eradicating invasive populations, repeated aerial insecticide-bait sprays followed by the release of sterile males (Sterile Insect Technique = SIT), has drawn criticism from urban populations being sprayed and from conservationists concerned with the effects of broadly applied insecticides on nontarget organisms ranging from beneficial insects to fish (Clark et al. 1996). The same objections could be raised to the annually repeated bait sprays needed to suppress established pests for the protection of crops or of fly free zones, such as the Caribbean fruit fly (*Anastrepha suspensa* [Loew])-free zones in Florida that help secure international markets for citrus exports (see Riherd & Jenkins 1996).

One solution to these problems is more precise delivery of insecticide. If pests could be attracted to a relatively few points where they would either come in contact with or consume the toxin then many of the objections that confront broadcasted pesticides would be

overcome. Such "bait stations" and related devices have a long history in tephritid control. For example, males of a number of *Bactrocera* spp., including the Oriental fruit fly *B. dorsalis* (e.g., Sivinski & Calkins 1986), are so highly attracted to methyl eugenol laced with an insecticide that it is possible to eradicate even well established populations through male annihilation (Steiner et al. 1965). This bait and toxicant mixture is often presented on wooden or cardboard surfaces or applied as a gel on structures such as telephone poles. *Rhagoletis pomonella* (Walsh), the apple maggot, has been suppressed to commercially acceptable levels by hanging red spheres, a visual attractant, covered with an adhesive trapping compound on orchard trees (Prokopy 1975). Similarly, female papaya fruit flies, *Toxotrypana curvicauda* Gerstaecker, are attracted to green spheres, particularly with addition of the male-produced sex pheromone, and when strategically placed along the margins of groves these traps can provide substantial control. (Landolt et al. 1988, Aluja et al. 1997). At the time of his death the late Dr. Everett Mitchell of the USDA-ARS Center for Medical, Agricultural, and Veterinary Entomology in Gainesville, Florida had developed an "attract and kill" system that he believed had wide applicability to a number of agricultural systems including tephritid area wide management. The station appeared to have a relatively long period of persistence in the field, and could be easily colored and provided with either pheromones or food-based attractants to increase its efficacy. In the following study we compared the "Mitchell station" (=MS), with and without the addition of a food-based attractant, to standard traps used for the capture of *A. suspensa* and other fruit flies, the McPhail trap and the Multi-Lure® trap (a plastic, McPhail-like trap; Multi-Lure, Better World Manufacturing Inc., Fresno, Calif.), under semi-natural conditions in field cages. Following testing in field cages, the MS was deployed in a citrus grove to determine its effect on previously-released populations of sterile *A. suspensa*.

Materials and Methods

Mitchell Station (MS). The MS consists of a badminton shuttlecock, (Sportcraft, LTD. Mt. Olive, NJ 07828, item # 00094) 5.3 cm diameter at the base, 2.5cm diameter at the apex, and 7.5 cm high; an attractant and a toxicant. The MS were painted green (Ace® Glo Spray Fluorescent 17054 GO GO Green) for field cage tests and yellow (Ace® Glo Spray Fluorescent, 17052 Solar Yellow, Ace Hardware Corp. Oak Brook, IL 60521) for field tests. Both colors are known to be attractive to *A. suspensa* (Sivinski 1990), and were judged to offer the maximum contrast in the different situations. The shuttlecock was thinly coated with 1 g of a mixture of Teflon® grease (Reese Teflon® Hitch Ball Lube, Reese Products Inc. Elkhart, Indiana, Oakville, Ontario, L6K 2H2 Part No: 58117) mixed with the contact insecticide permethrin (at a ratio of 6% permethrin to Teflon® grease wt/wt). The toxicant permethrin is a pyrethroid that has low to moderate toxicity to humans and other terrestrial vertebrates for short-term exposures (National Pesticide Telecommunications Network, Oregon State University, http://ace.orst.edu/info/nptn/). It is, however, toxic to fish, and to bees which find it highly repellent.

Food-based attractants for the MS, Multi-Lure and McPhail traps. The 5 g ammonium acetate (=FFA) and a 50 mg putrescine (=FFP) Biolure® 2-component fruit fly lure (Suterra, Bend Oregon 97702) were positioned one each back-to-back, extending downward on a wire, inside the cavity of the shuttlecock, protruding 2 cm below the base of the MS. In the field cages both the Multi-Lure (Better World Mfg. Fresno, CA 93727) and the standard glass McPhail traps contained a 350 ml solution of 10% water and propylene glycol (=PG) (see Thomas et al, 2001) into which flies fell and drowned. Between the first and second field tests, the BioLure® attractant was replaced with an aqueous solution of 4 torula yeast/borax tablets (ERA Int. Ltd., Baldwin, N.Y. 11516) in 350 ml of water, another

approved Tephritid attractant (as per Anonymous 2004). (This change was prompted visually, due to suspect BioLure® content deficiency/consequent suspect longevity of the attractant.)

Source of insects. *Anastrepha suspensa* were obtained from a long-standing colony, (> 5 years old) maintained at the Florida Department of Agriculture and Consumer Service's Division of Plant Industry in Gainesville, Florida. Flies were 7–12 days of age at the time of testing, and had been irradiated as pupae at 7 kR, 48 hours prior to eclosion. Despite reduction in behavior, i.e. signaling/ mating/ longevity of irradiated flies, these were utilized to provide the numbers needed for analysis purposes, as appropriate numbers of wild populations in the test site were lacking. Subsequently they had been provided with a diet of sugar and protein and with an excess of water. Food was removed 24 hours prior to the experiment in order to enhance their response to food cues, perhaps not simulating what occurs in a field situation, but not an uncommon occurrence when testing pesticide efficacy under laboratory conditions.

Time between insecticide exposure and death. Flies attracted to traps are immediately available for counting. But those exposed to an insecticide might disperse from the vicinity of the station and die later. This influences both the time at which samples of dead flies should be obtained and the locations within the cages where bodies might accumulate. Therefore, it was important to determine the length of time between contact and/or ingestion of the insecticide and the collapse and death of the fly. In laboratory test's, flies seized by the wings with forceps were held with tarsal contact for 3 seconds on the MS until feeding was observed or for 30 seconds (which ever occurred first). Flies used as controls were held by the wings with forceps for same period. Flies were placed in plexi-glass/ screen holding cages (21 x 21 x 21 cm) with water soaked cotton and a piece of diet containing sugar and protein. Three replicates were performed each using 10 flies. Observations for mortality were taken every 15 minutes from time of exposure.

Field cages. Screen mesh field cages (290 cm diameter x 200 cm height) and supported by exterior frames of PVC pipes were erected in an open field on the grounds of the USDA Center for Medical, Agricultural and Veterinary Entomology in Gainesville, Florida. Shade cloth was placed over the roofs of the cages and down their eastern walls. The floor and the bottom of the side of the cage was then placed inside a plastic wading pool (2.4 m diameter x 0.5 m high) filled with 25 cm of water. As a result, flies that died on either the ceiling or the walls of the cages fell into the water, where they were protected from foraging ants and easily collected and counted. A minimum-maximum thermometer was placed under the eastern wall-shade cloth of one cage and temperatures recorded daily.

Sample schedule for field cage test. The mortality inflicted by the MS was compared to that of fly catch in the Multi-Lure and McPhail traps in a set of 5 treatments: 1) MS without attractant, 2) MS with FFA/FFP attractant, 3) Multi-Lure trap with FFA/FFP and 10% PG attractant, 4) McPhail trap with torula yeast/borax solution attractant and 5) untreated control, i.e. no trap or bait-station. Each field cage contained only one treatment at a time. It was suspended 10 cm from the center of the top of the cage. Fifty male and 50 female flies were introduced at 0730 h and the bait stations / traps removed at 1200 h. The counting and removal of dead flies began at 0800 h and continued hourly until 1400 h in order to take into account any insects that might have been exposed to insecticides prior to 1200 h but had not yet died. Dead flies removed from the wading pools were tabulated individually for each treatment, and in the case of treatment 3 and 4 were not added to the total of live flies trapped. This morning and early afternoon sampling was done to minimize any variance that might be generated by the daily increase in the summer heat. Following the last count of dead flies all remaining live insects were captured, counted and removed. Treatments were rotated daily, and each treatment was presented in each cage 5 times for a total of 25

replicates. After each treatment had been exposed in each of the five cages, the treatments were removed and newly prepared treatments were used for the following test replicate – five in all for treatment rotation.

Field test. The field-plot test employed two of six ca. 0.4 hectare plots of mixed-variety oranges, *Citrus sinensis* Osbeck (Fig. 1). The test was conducted at the University of Florida's Horticulture Teaching farm in Gainesville. Data was collected between November 17, 2003 and March 2004. Sterile adult *A. suspensa* obtained from 500 ml of pupae (~17,000–20,000 insects) were released in the centers of the plots one day prior to MS deployment in order to allow for dispersal throughout the plots. (Pupae were eclosed in boxes and fed water and sugar in the form of agar blocks prior to release.) Twenty-one MSs were then hung on the northeastern sides of trees, one per tree, at heights of 2–3 m. in one of the plots in the pattern described in Fig.1 a–f and left for a period of 7 days. MS density was judged to reflect commercial realities, i.e., much higher densities would not normally be feasible. Nothing was placed in the Control plot during this period. The MSs were then removed 12 Multi-Lure traps containing the 2-component BioLure® attractant (Replicate 1) or the 12 Multi-Lure traps baited with an aqueous torula yeast/borax solution (TYB) for Replicate 2-6, were placed on the northeastern sides of trees at heights of 2–3 m. in the pattern described in Fig. 1 a–f in both the treatment and control plots. These were left for 7 days and their contents were then collected and counted. The plot with MS's and the non-treated plot were reversed for the following replicate. The same two plots were used the entire test – to maintain a constant buffer between test plots. Again, after the 7 day exposure period, stations were removed and traps were set. Following the trap servicing, flies were immediately released. (Flies were dyed with plastic pigment to monitor movement/longevity.) FFA and FFP were replaced at four-week intervals. TYB was replaced at each trap service interval. A total of 6 replicates were performed. Because of unseasonably cold weather conditions, the numbers of released flies and exposure times for MSs and traps were doubled in the final replicate.

Statistical analysis. Although care was taken to introduce exactly 50 male and 50 female A. suspensa into each field cage, the numbers recovered were often somewhat different, the reason as indicated above, and percentages were calculated for the analysis. The range of these percentages was insufficient to require arcsin transformations (e.g., Southwood & Henderson 2000). Comparison of means was through ANOVA followed by a Waller's test (SAS Inst. 1989). Due to modifications in fly-release rates and exposure times during the experiment, field plot captures were compared by a paired sample, non-parametric test, the Wilcoxon Paired-Sample Test (Zar 1974).

Results

Time to death. Flies exposed to the MS in the touch-tests died within 30 minutes of exposure. The first fly to die in the control was recorded 2 hours and 45 minutes after being placed in the holding cage and after 24 hours, a total of two flies had died in the control cages. Because exposed flies tended to die within 1 hour following exposure to the toxicant, it was believed that fly collections in the field cages, that began 2 hours after the removal of the MSs, would be certain to obtain all the flies that had been exposed to the MSs and died as a result.

Trap comparison. Each of the 5 treatments differed significantly from each other. However, of the most importance was the results observed with the MS and not the McPhail/Multi-Lure traps. The latter traps are not being proposed as "attract and kill" devices, but in essence were utilized as comparison value only. The addition of the attractant improved the performance of the MS ($F = 78.8$, d.f. = 4, $P < 0.0002$; Fig. 2).

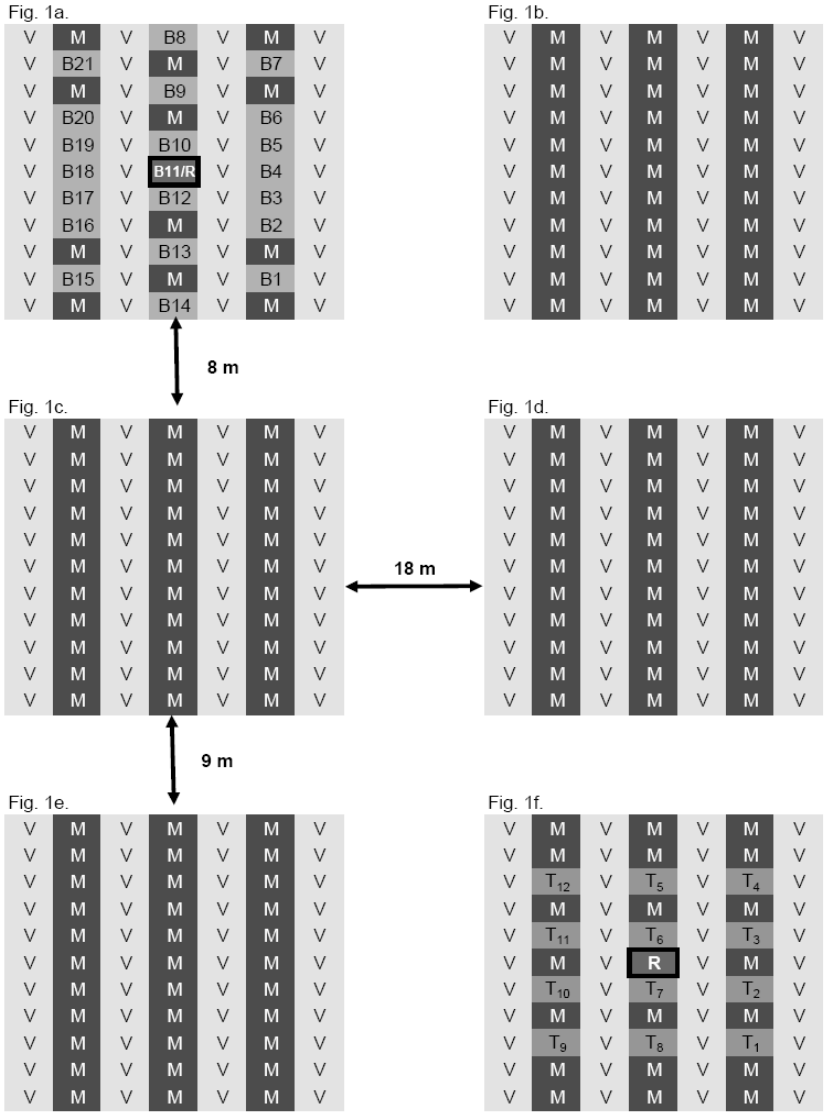

Figure 1. a–f. Field-plots used for testing the efficacy of the Mitchell Station. T= Multi-Lure trap, B= Mitchell Station, T + a number/ B + a number indicates trap/station site(s), M= mature citrus trees of similar size (3-4m), V= citrus trees of varying maturity, R= *Anastrepha suspensa* release site. Plot's "a" and "f" were used for the tests and treatments (the Mitchell Stations and traps) and were rotated between them following each treatment sequence.

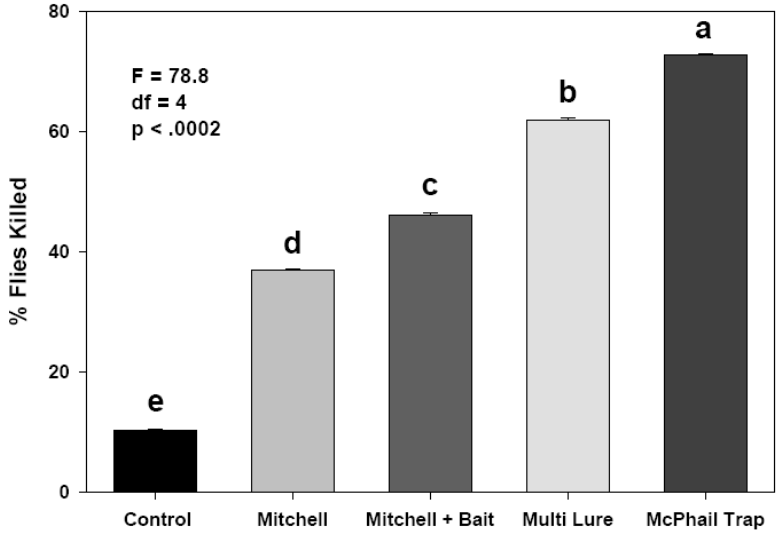

Figure 2. The mean percentages (SE) of *Anastrepha suspensa* that died in field cages that either contained a Mitchell Station without an attractant, a Mitchell Station with an attractant, a Multi Lure trap with an attractant or a McPhail trap with an attractant. The control contained no device. Means that share a letter are not significantly different.

MS efficacy in the field. Significantly fewer flies were captured in the citrus plots that had previously contained MS (T = 0, n = 6, P (2-tailed) = 0.05; Fig. 3). Therefore, at best, i.e. in lieu of the lack of a commercialized bait station, the MS results demonstrates the potential use of the device in State/Federal fruit fly detection program's. At minimum, the results from this study, provides a standard in which to measure the efficacy of other candidate bait-stations.

Discussion

In field cages, the efficacy of the MS (in terms of fly exposure to a toxicant), did not perform as well as either the Multi-Lure or McPhail traps, (in terms of flies recovered from a non-treated control). However, it is a considerably simpler and less expensive device that could be deployed in relatively large numbers, rather than traps, to reduce wild Caribbean fruit fly populations. The initial field cage results seemed sufficiently promising to examine the MS more fully in a field trial. Field tests found that a concentration of ~52 MS/hectare significantly suppressed a free-ranging *A. suspensa* population. Whether or not the suppression was of an economically important level, this first successful field deployment of a bait station for the control of *A. suspensa* now allows other designs to be compared to a standard of demonstrated efficacy, i.e. similar to a standard operating procedure recently developed by USDA-APHIS-PPQ to evaluate candidate lures/traps for Cooperative State/Federal Fruit Fly Detections Programs. In addition to the ability of the MS to kill flies, other characteristics are likewise contributory in the use of a bait station that might be deployed in both populated and agricultural areas. Particularly are the station's potential danger to non-targets such as people, birds, and beneficial or benign species of insect. In the case of beneficials,

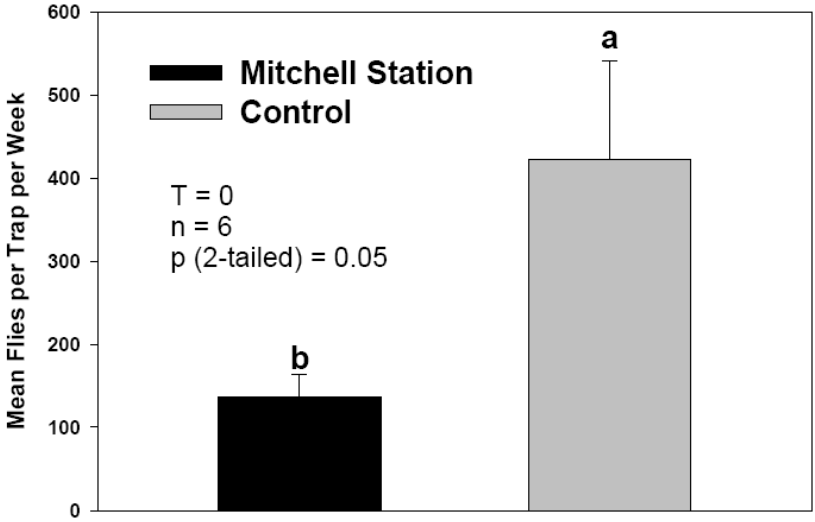

Figure 3. The mean (SE) numbers of *Anastrepha suspensa* captured / week in field plots that had either previously contained "Mitchell Stations" or were untreated controls. Letters above the means represent a significant difference.

a contact insecticide such as permethrin poses an inherently greater risk than an insecticide that must be ingested to take effect. Specific fruit fly parasitoids, for example, that might be attracted to a station's color but are not stimulated to feed by bait odors, would appear to be in more peril from the permethrin in the MS than they might from a hypothetical station containing an insecticide such as Spinosad which has demonstrated little effect on many opiine Hymenoptera (e.g., Vargas et al. 2001, see however Mason et al. 2002). Permethrin is relatively nontoxic to terrestrial vertebrates, but a station with a "grease" covering, such as the MS, would have to be carefully placed in urban areas to avoid any contacts with inquisitive bystanders.

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